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ABSTRACT

This study investigated the problem-solving performance of education undergraduates while engaged in the solution of complex, data-rich, real problems in a computer environment. The problem used was the riddle of the frozen wooly mammoths. Two instructional programs were used: the problem mode (I) engages the problem-solver in the data base with minimal instruction; the heuristic-discovery mode (II) reacts to the internal logic and consistency of input from the problem-solver by means of heuristic feedback. Multifactor ANOVA results favored mode I for number of requests for data, time search in problem space, number of data matches, and number of data matches per unit time. No differences were observed between modes I and II for number of requests for data per unit time and number of hypotheses generated. (Author/MLH)

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PROBLEM-SOLVING BEHAVIORS AS A FUNCTION OF INSTRUCTIONAL MODE, CONCEPTUAL SYSTEM, AND FIELD INDEPENDENCE IN A CAI ENVIRONMENT

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Problem Solving

Problem solving behavior has been investigated and discussed from numerous and varied points of view. Dewey's (1910) preference for problem solving projects and do-it-yourself learning produced a significant effect upon educational practices and philosophy during the present century.

Many previous investigations of problem solving were generally focussed on simple problem solving tasks such as puzzles, anagrams, or simple tasks with a few operations and characterized by a unique solution. (Bloom & Broder, 1950; Durkin, 1937; Duncker, 1945; Katona, 1940; Luchins, A. S. & Luchins, E. H., 1970a, 1970b, 1970c; Luchins, A. S., 1942; Maier, 1930, 1970; Wertheimer, 1945). These studies investigated how individuals go about the solution of practical problems (Duncker, 1945) or the effect of the nature of the problem upon the problem solving process (Durkin, 1937) or Maier's (1930) research into the human reasoning process and the importance of providing direction in the problem solving situation.

A. S. Luchins (1942) was concerned with the nature of relationships between the teacher's instructional behavior and the pupil's problem solving performance. Specifically, he was concerned about the relationship between set and rigidity or stereotype in problem solving, wherein a particular behavior pattern is repeated although it has been proven to be unsuccessful.

Many researchers (Fattu, 1954, 1964; Bloom & Broder, 1950; Simon, 1975) argue that the study of how the problem solver formulates and attacks the problem will ultimately provide more payoff than attempting to ascertain whether the problem situation arrived at was correct or incorrect.

Cognitive Style

The concept of learning styles as independent of general intelligence has been given the name-cognitive style. Individual cognitive style differences have been investigated by many researchers and have been labelled by a variety of descriptive terms or constructs. For example, early studies in rigid vs flexible modes of functioning have been reviewed by Leach (1967). These have been followed by investigations of cognitive styles such as focussing/scanning (Bruner, 1956); abstractness/concreteness (Harvey, etal, 1961); field dependence/independence (Witkin, 1962); reflectivity/impulsivity (Kagan, 1963); wholists/serialists (Pask, 1969). The magnitude of the effort expended in this area of research and the number of cognitive styles formulated would serve to support the premise that factors of a nonintellective nature must be operating in learning and problem solving tasks within individuals and thus represent valid avenues of investigation if educators are to successfully blend programs, teachers, and pupils into the most effective and productive learning environment.

For more than two decades (Witkin, 1962, 1972, 1973) centered his activity around what he had labelled as modes of functioning or cognitive style. He suggests that these cognitive styles represent a potent variable in how students learn and how students and teachers interact in the classroom.

Harvey (1961, 1966, 1968) and his group of investigators found that an individual's beliefs as it leads to conceptual systems and results in some degree of abstractness affects the learning environment of the classroom as it relates to learning effectiveness and teacher-pupil interaction.

Many investigations of problem solving have focussed their attention and efforts on the effects of individual variables such as IQ, sex, and age upon problem solving success. Another line of research studied how these individual differences interact with a particular problem type or teaching strategy employed. Cronbach (1966) poses the possibility that research needs to incorporate complex experimentation and explore what he refers to as a five-fold interaction; contrasting subject matter, type of pupil, timing of instruction, and the outcomes. Cronbach suggests that these interacting variables have more to do with the personality of the individual learner than their ability.

Statement of the Problem

The purpose of this research was to investigate selected aspects of human problem solving behaviors as a function of the two cognitive style variables of Conceptual Systems (CS) and Field Dependence-Independence (FD-I). The effect of the problem solving environment (i.e., guidance provided to the subject) upon the behaviors exhibited by the Ss was also investigated. Foremost, this study attempted to respond to Cronbach's (1957, 1966) recommendation for a need for more research to investigate multiple interactions and attempts to coordinate individual differences with experimentation. This study represents a multidimensional assessment of cognitive styles. Specifically, do cognitive styles play significant roles in the problem solving endeavors of human subjects?

CAI Program: The Wooly Mammoth

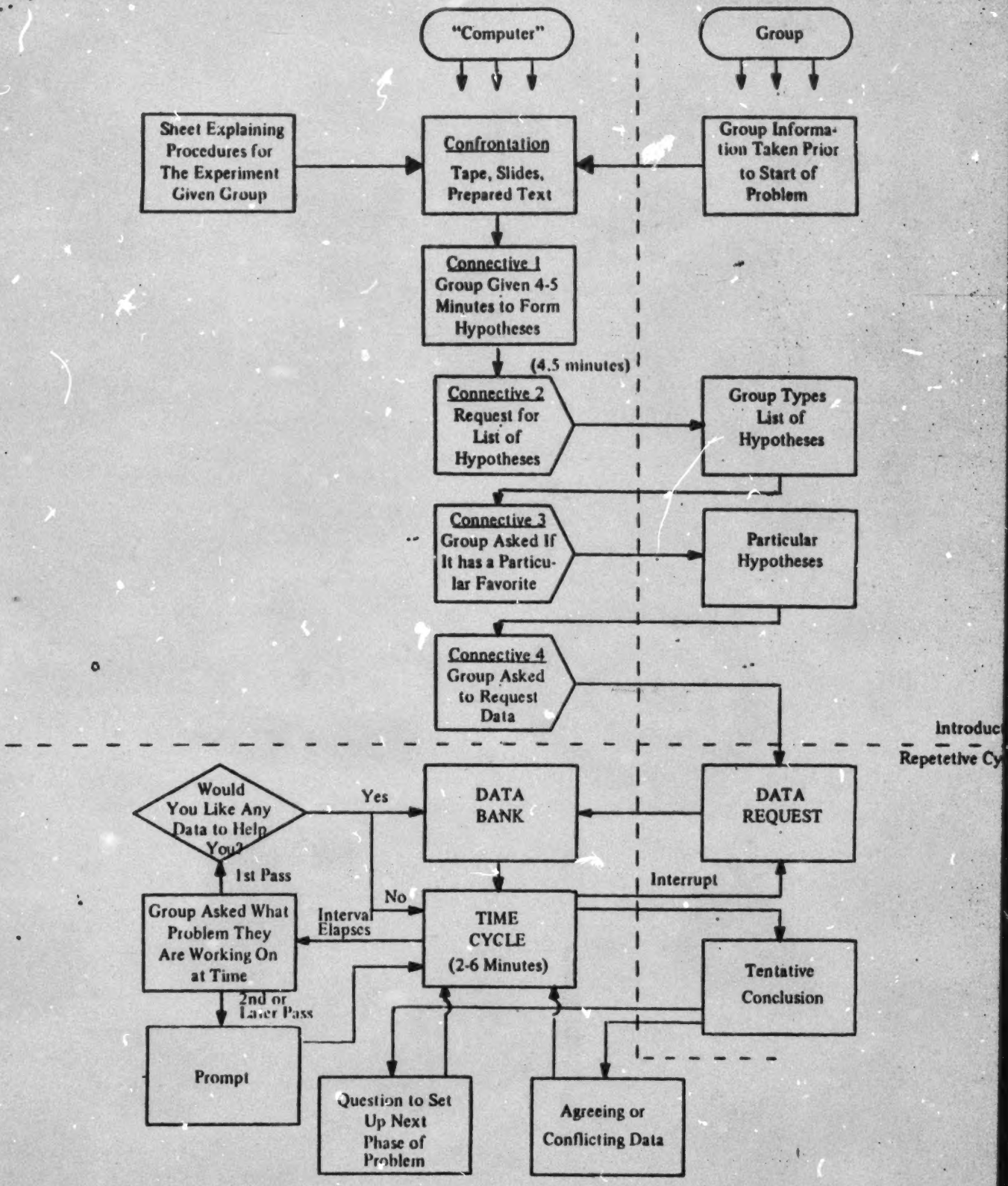
Overview:

The Wooly Mammoth (Mammo) problem is a problem-solving environment designed to confront individual or small groups of problem solver with a complex task. The role of the computer (an IBM 1500 series using Coursewriter II with CRT, image, and audio terminals) is to : (1) present the problem to the student; (2) serve as a data source; (3) monitor selected parameters useful in the study of problem solving; and (4) provide statements (heuristics) which help structure the flow of the solution effort.

Operation

An operational flowchart of student progress through the two-hour Mammo sequence is presented in Figure 1. The program first handles housekeeping details and presents the Confrontation (Appendix 1) to the student. Then, without identifying the problem to be solved, the computer requests possible hypotheses and suggests the student query the computer (request data) that might be useful in testing the hypotheses. At no time does the student see a listing of available data. Instead, he types in a natural language request (up to three lines of text) which is matched with stored data titles using an edit and a keyword routine.

For example, a student might request, "What was the age of the mammoths?" This simple statement is deceptive. Does the student wish to know the number of years since mammoths became extinct? the actual age of the Beresovka Mammoth at death? the actual age (average) of mammoths at time of death in general? This example points out: (1) difficulties of using a computer to assign semantic meaning to a string of characters



SIMPLIFIED FLOW DIAGRAM FOR MAMMO

Figure 1

and; (2) the tendency of problem-solvers to formulate imprecise data requests. A successful data match results in the display of verbal data on the image screen. An unsuccessful data match triggers the data request sequence again, but in a slightly different form. The student is given the three options of making a final conclusion and ending the program, reviewing hypotheses, or making another data request.

The data request used as an example will trigger display of a brief passage regarding the geologic age of the mammoths, abstracted from the journal, Science. There are more than 200 separate pieces of data stored on randomly accessed images.

This describes one version (Mode I) of Mammo, called the Problem-Mode; Mode I was designed to be free from hints or cues, both content-oriented and content-free, that might aid the student in solving the problem. A second mode (II) has been constructed to provide content-free problem solving heuristics to guide, shape, or direct the process used by the student.

Operationally, Mode II is identical to Mode I except for two added features. The first is quite simple: it forces the student to evaluate his progress (hopefully, to test hypotheses with the data acquired) by requiring the student type a brief conclusion after he has received data.

The second feature unique to Mode II is the presentation of selected heuristics to "guide" the problem solving approach used by the student. By responding to the pattern of data requests or conclusions posed by the student, Mode II heuristics simulate a real problem-solving environment. Two examples will be presented. If the student triggers three pieces of data which have been determined to be logically related (by an outside authority), he receives the following heuristic message:

"Good. Your last few requests for data show that you're following a single line of thought. This is the only profitable way to attack a complex problem like this."

If on the other hand, the data requests (and matches) indicate logically unrelated data being sought, the heuristic may be of the following form:

"Do you have some strategy or plan of attack on the problem? What are you really trying to clarify?"

As another example of the second unique feature of Mode II, the conclusions made by students are compared with prestored conclusions which have been posed by scientists who studied the riddle of the mammoths. Further, logical "chains" or sets of data which are necessary and sufficient conditions to support these conclusions have been identified.

Presume that a student concludes that the mammoths froze to death but the student has neither requested nor seen the necessary data "chains" to support this conclusion. The likely computer heuristic displayed to the student, depending on specific terminology used is:

"A comparison of all possible facts and data in memory areas implies that you have seen insufficient data to form this conclusion."

On the other hand, suppose the student has requested the necessary data and concludes the mammoth froze to death. In this case, the heuristic is:

"Hold on! Let's go back and check out your conclusion about the mammoth's death. Ask yourself questions like--if the mammoth really died in this way, what condition would the cadavers be in? Always check your conclusions. Consider the idea and determine what data you need to check your idea out, then request such data."

From these heuristics, it can be seen that the intent of the guidance provided in Mode II is to urge the student to formulate hypotheses, devise critical tests of these hypotheses, request data needed for those critical

tests, and apply the tests in some logical fashion to reducing the discrepancy between the problem statement and the solution statement.

Method

Subjects-Tests

Three-hundred-twenty education undergraduates enrolled in courses in educational psychology and educational media were administered the Otis Quick-Scoring mental Ability Tests, The Group Embedded Figures Test (GEFT; Oltman, Raskin & Witkin, 1971), and the Conceptual Systems Test (CST; Harvey & Hoffmeister, 1971).

Procedure

The subjects were classified into two levels of analytic ability (GEFT) and three levels of abstractness/concreteness (CST). One-hundred-twenty subjects were randomly selected and paid to participate in the experimental procedure. Those subjects participating were then randomly assigned to either problem mode (I) or heuristic-discovery mode (II) treatment levels from joint I.Q. and sex strata.

Data Sources

The problem solving behaviors selected as criterion variables included the number of data requests (NUMDAR), number of data matches (NUMDAM), time spent by the subject interacting with the CAI program - "The Wooly Mammoth" (TIMESRCH), data requests per unit of time (DARPERT), data matches per unit of time (DAMPERT), number of hypotheses generated by the subject (NUMHYP),

and the quality rating of the hypotheses (QUALRAT). Data were analyzed using a series of multifactor ANOVA designs and the .05 level of significance. Criterion data were collected during the two hour experiment which took place on line with the interactive CAI system.

An adapted version of Quinn's (1972) hypothesis rating scale was employed to determine the value of QUALRAT for each hypothesis pr ented by the subjects. An inter-judge rater reliability of r_s=0.86 was obtained through independent ratings of more than 200 hypotheses.

Results

Significant differences which favor Mode I (Problem-Mode) were found for the criterion variables of NUMDAR, NUMDAM, TIMESRCH, and DAMPERT. No significant differences were observed between Mode I and Mode II in regards to DARPERT, NUMHYP, and QUALRAT.

The data did not support the rejection of the main effects of the null hypotheses comparing abstract with concrete (CS) Ss and non-analytic with analytic (FD-I) Ss.

Significant results were obtained in the analysis of NUMHYP and Conceptual System. The results as indicated in Figure 2 and Table ' (next page) suggests that Ss who were identified as concrete (CS_1) by the CST test generated a significantly greater number of hypotheses than their more abstract (CS_3, CS_4) counterparts. These results are consistent with the theory of Conceptual Systems as posited by Harvey (1961, 1966, 1968) and the results obtained in an earlier study by Sieber (1965).

Two way interaction effects between mode of presentation and CS and degree of analytic (FD-I) ability were not significant. Possible relationships among variables were explored through correlational analyses to permit an assessment of the clarity of results.

	CS_1 Concrete	CS_3	CS_4 Abstract
Mode I Problem-Mode	4.056	2.944	2.833
Mode II Guided-Heuristics	4.111	2.390	2.833

Figure 2. Basic Research Design with mean scores obtained from NUMHYP

TABLE 1

ANALYSIS OF VARIANCE OF NUMHYP

Source of Variation	df	ms	F-Ratio
Conceptual System	2	23.583	7.726*
Mode	1	0.750	0.268
Interaction	2	1.028	0.368
Error	102	3.794	
Total	107		

$F_{(2,102;0.05)}=3.09$

Summary

The importance of this study stems from the immediate outcomes and the long rang implications of the developing data base from investigating complex problem-solving behaviors. The lack of effects of CS and FD-I might constitute a valid observation or it might reflect error involved in the gross classification of individuals. Moreover, these results agree with those obtained in a study by Bissiri (1971) and do not support the suggestion by Harvey (1961) that there exists a relationship between some elements of CS and FD-I.

The results and experimental procedure indicated that Ss without previous experience at a CAI terminal were able to perform and adapt to this environment as well as those Ss who were familiar with CAI.

The success encountered in building a computer environment which is sensitive to a wide range of strategies employed by learners in a non-restrictive natural language setting provides encouragement to explore more fully numerous instructional strategies to train problem-solvers.

Appendix I

Confrontation

INSTRUCTIONS

1. Before reading the following information you should have typed r (or any other letter) and entered it.

The Arctic Ocean is bordered across most of Eurasia and North America by low, mostly flat plains that dip gently into the sea, called the tundra. With an average annual temperature of two degrees above zero the tundra remains frozen most of the year. When the spring thaws the snow in the higher lands to the south, the water runs into the river and begins a migration to the Arctic Ocean, but the mouths of these great rivers are still frozen solid in these cold, northerly reaches and present an impenetrable dam to the advancing waters. The water spreads out over the low landscape forming innumerable lakes, ponds and swamps. The water has no choice but to sit and wait for the thawing of the river mouth -- it can't evaporate into the cold air, and it can't sink into the ground because it's permanently frozen to depths of hundreds of feet.

About one seventh of the entire land surface of the earth is permanently frozen. The surface of some of this territory is bare rock, but the greater part of it is covered with a layer, varying in thickness from a few feet to more than a thousand feet, of stuff we call muck. This is composed of an assortment of different substances, all bound together with frozen water, which becomes and acts as rock. While its composition varies considerably from place to place, it is usually of earth or loam and organic matter. Only the top two or three feet of the muck ever thaws in the short arctic summer, only to freeze solid again during the winter. Ten feet down the passage of the seasons goes by completely unnoticed.

When the mouths of the great rivers finally open, much of the water drains away into the Ocean, carrying some of the muck with it. Then, occasionally, the excavated muck leaves to reveal one of natures great oddities, the frozen remains of the great wooly mammoth.

The most famous of these, the Beresovka mammoth was discovered by a Siberian tribesman around the turn of the century. It was sticking head-first out of a bank of the Beresovka River, a tributary of the large Kolyma which empties into the Arctic Ocean. This man axed off the tusks and took them for sale to the nearest trading post, at Yakutsk, and here he told the Cossack who bought them about the rest of the animal. Now there was an edict from the Czar in force at the time that all mammoth or other frozen animal finds were to be reported to the government. This the Cossack did, and a scientific expedition was sent by the National Academy of Sciences from St. Petersburg. The members of this company built a shack over the corpse and lighted fires within to thaw it out. They then dismembered it carefully, packed up the parts, refroze them in the air outside, and sledded them to the Trans-Siberian Railroad.

Much of the head, which was sticking out of the bank, had been eaten down by wolves and other local animals, but most of the rest was perfect. Most important, however, was that the lips, the lining of the mouth and the tongue were preserved. Upon the tongue as well as between the teeth, were portions of the animals last meal, which for some reason he had not had time to swallow.

This meal proved to have been composed of delicate sedges and grasses and most remarkably - of fresh buttercups in flower. The stomach contained many more quarts of the same material, undigested and not decomposed. The exterior of the mammoth was whole and perfect with none of its two foot

hair rubbed or torn off. The meat was fresh, although it started to rot when thawed, and the sled dogs ate it with enthusiasm relieving the party from carrying additional supplies for the dogs. Unlike most mammoth finds the Beresovka mammoth had a broken hip, but like others it was healthy and robust, upright and with no apparent cause of death.

Mammoth remains are found widely distributed over Siberia and in Alaska. Their bones are spread over the floor of the Arctic Ocean where ships have dragged them up. And, 200 miles to the north, in the New Siberian Islands, not much farther from the North Pole than Chicago is from New York, mammoth remains are thickest of all.

Perhaps using the computer as a resource you may be able to determine some possible causes of death for these mammoths. The computer has been programmed to provide a wide range of data that may be beneficial to you.

Now type r (or any other letter) and enter.

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